Noise Mapping of an International Transportation Route

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The Windsor-Detroit border crossing is a gateway for North-American goods coming to and from Canada and the U.S. It is the largest border crossing in Canada and relies heavily on the smooth operation of the Ambassador Bridge. Huron Church Road is the main transportation route leading to the bridge, which sees on average 32,000 vehicles cross daily and often as many as 50,000 vehicles during peak times. The local area surrounding the bridge and Huron Church consists mainly of residential areas, where noise pollution can greatly affect the health and quality of life of the people living there. The issues are very evident and of concern to the local community, and various solutions are being lobbied.

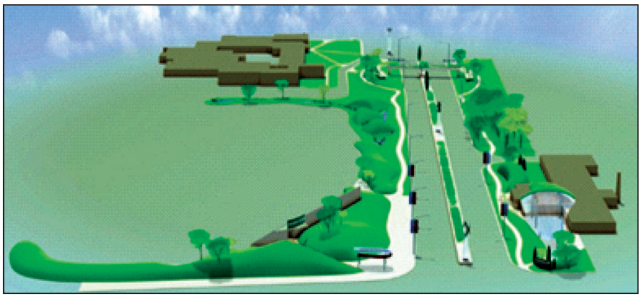

Figure 1. Artist conception of Green Corridor section of study area.

Windsor Environmental Noise Mapping Initiative (WENMI) is a unique project in North America first envisioned as a fourth-year design project for University of Windsor engineering students. Its purpose was to study the current condition of Huron Church Road and engineer a reliable noise contour of the local area. By providing the public an accurate and reliable analysis of the area, it can potentially aid in the decision process toward a positive solution and create awareness about noise pollution.

Essentials

Various terms specific to acoustical engineering must be understood to interpret the results. Some local initiatives are also summarized to allow for a common understanding of the area.

Terminology.

- Decibel (dB) – A logarithmic unit of measurement that expresses the magnitude of a physical quantity (usually pressure, power or intensity) relative to a specified or implied reference level.
- A-weighted scale – An adjusted decibel scale better representing the nonlinear hearing capabilities of humans.
- Noise contour – Analogous to a thermal image, it allows the visualization of varying sound levels.

Local Initiatives. The Green Corridor Project is a ground-breaking initiative for generating a green redevelopment of the international bridge corridor linking Canada to the United States. It involves a 2-km stretch of Huron Church Road leading south from the Detroit River. This development was created from an artistic perspective as shown in Figure 1 and did not contain any acoustical engineering parameters.

Legislation. Regulations in Ontario establish 55 dBA during the day and 45 dBA at night as the allowable guideline noise level in a residential zone. New residential areas surpassing the 55 dBA are required to employ noise mitigation measures to help suppress the noise levels to acceptable values. However, residences built prior to the introduction of noise legislation are omitted despite the potential for adverse effects.

Area of Interest

Huron Church Road extends approximately 6.6 km (4 miles) in Windsor, Ontario, connecting Highway 401 to the international river crossing. WENMI focused on the stretch extending from the Detroit River down to the EC Row Expressway (5 km). A width of 500 m east and west of the road was included in the calculation area to ensure the effects of the noise pollution were sufficiently accounted for in the surrounding region.

The 5-square-kilometer stretch of road shown in Figure 2 was chosen due to the sensitive noise pollution issues associated with the area and the desire to analyze and better understand the problem. The area contains the University of Windsor campus, a large residential area, several local industrial plants, and numerous commercial businesses. It has been publicly acknowledged that an issue regarding bridge traffic exists, and several solutions are being considered. Studying this area would provide a good basis for the public and government to better understand the current situation and allow for the simulation of proposed ideas and their influence on noise levels.

Purpose

The goal for this project was to establish a reliable noise emission contour and raise public awareness about environmental noise pollution. We hope that the results will be a stepping stone in improving health and quality of life for local residents. Providing a reliable and proven 3D acoustic model, including consideration of various mitigation solutions, can be created through simulation techniques. This will ensure that mitigation solutions are effective and engineered optimally.

Road to Success

Modeling Program. There were several programs available to WENMI for 3D modeling and simulation. After careful consideration, Brüel & Kjær Lima™ software was chosen due to its extensive and detailed capabilities and excellent technical support. Some key features included 3D modeling, reverse engineering, soundscaping, and the ability to superimpose industrial noise sources with transportation noise. Even though the Lima program's capabilities are greater then what was required for this project, it allows for further studies at the graduate level.

B&K Support. Choosing such an advanced and capable modeling program like Lima also had the disadvantage of a large learning curve. To ease the difficulties of using a new program B&K provided WENMI with excellent technical support and several Internet sessions. The web sessions were real-time interactive tutorials tailored by B&K specifically for the WENMI group based on difficulties in learning the use of Lima. These sessions provided a great deal of knowledge and significantly helped progress of the project.

Modeling Process. The modeling process was subdivided into three stages; preprocessing, processing and post processing. The initial step in obtaining a noise contour was creating a 3D image of the area. This was achieved by creating numerous "polygons," each representing an object of interest. These mainly pertain to residential, industrial, commercial buildings, and roads. A bitmap containing real images was imported into Lima for visual aid and assisted in accurately modeling the polygons. The 3D image in Figure 3 illustrates the model. The green areas represent residential housing, the blue and white shapes represent industrial and commercial properties and the green lines represent roads.

Several assumptions were made to establish a three-dimensional model due to variances in residential dwelling designs and the topography of the region. Residential houses were assumed to have

Figure 2. Study area illustrating significant points of interest.

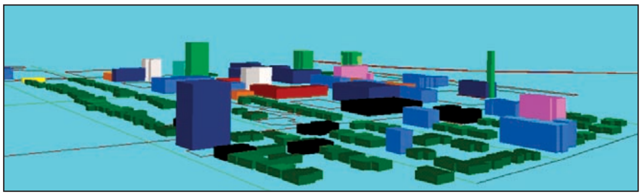

Figure 3. Three-dimensional image of Lima model that shows area buildings and topography.

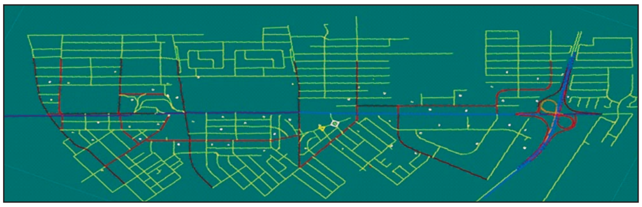

Figure 4. Location of roadways within the model that contain significant traffic volumes.

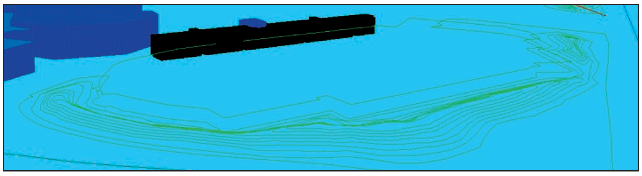

Figure 5. Topography details of earth berm surrounding the University of Windsor Stadium.

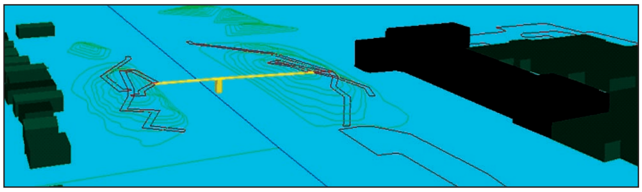

Figure 6. Topography details of pedestrian overpass atop of Huron Church Road.

a mean height of 5 meters, while larger structures like industrial plants or apartments had heights measured manually using a laser range finder for accuracy. The topographical area was also assumed to be flat, since there are negligible elevation changes in the region.

The most contributing components – the roads and their associated data – were represented as "line polygons." This allowed for the implementation of data pertaining to every single road. Some attributes included the number of lanes, traffic volume figures for small and heavy vehicles, and reflectivity factors for road surfaces. Data pertaining to major roads were obtained from the City of Windsor, while smaller roads were considered to be insignificant contributors due to their low traffic volume. Fifteen roads were assigned traffic data and are represented in red and blue in Figure 4.

Certain structures in the area required additional attention to model. The Ambassador Bridge and various walkways and berms along Huron Church Road needed to be implemented. Using dimensions obtained by field readings, aerial images, and Lima's 3D modeling capabilities, area-specific attributes were incorporated to ensure high accuracy of the model. From this, the Ambassador Bridge, several berms located around Alumni Field, an overhead walkway on Huron Church Road, and the EC Row Expressway overpass are all modeled. Illustrated in Figures 5 and 6 are close-up images of the Alumni Field berms and the nature bridge overpass located on Huron Church Road.

Industrial Noise Sources. The majority of the environmental noise pollution is caused by auto and heavy truck traffic, although several industrial sites are also located within the area. To maintain accuracy of the model, significant industrial noise contributors were accounted for. Third-octave L_{eq} readings were logged to quantify the industrial sources. The length of data acquisition depended on the time taken for L_{eq} readings to stabilize. Once collected, data were converted to the A-weighted sound power level and submitted into Lima as point sources. Industrial noise was represented as point sources due to their immobilized single point of origin, unlike a vehicle travelling on a road, which is represented as line sources.

When simulations are carried out, point sources are measured separately from road emissions. Industrial and road emission contours are calculated and then superimposed to provide a combined representative of both contours. The effect of the industrial source contributions is covered in the simulation portion of this report.

Data Acquisition. Readings were logged using B&K Type 2238 and Type 2250 sound level meters (SLMs), shown in Figure 7. These meters provided great versatility with easy-to-use interfaces.

Simulation. The completion of a three-dimensional model made way for the actual engineering work. The intent of the initial simulation was to make use of theoretical values to obtain a noise contour, then reverse engineer another contour using field data (discussed later), and finally compare the two simulations and optimize them.

For roadway noise, the model used the British Calculation of Road and Traffic Noise (CRTN) standard. Several incorporated European standards were available but unfortunately Canadian traffic models are not available yet within Lima. Creation of a custom standard is available in Lima, but due to time constraints, WENMI opted for CRTN, which is somewhat similar to the Ontario Road Noise Analysis Method for Environment and Transportation (ORNAMENT) standards. L_{eq} readings were divided into day and night output to enable analysis of noise pollution during both periods. Calculations for day emissions were taken at a height of 1.5 m, which represents the height of the residential backyards during

Figure 7. Brüel & Kjær Type 2238 and Type 2250 sound level meters used to acquire field noise data to calibrate Lima noise model.

the day and also provided uniformity. Night readings were simulated from a second-story window, or the equivalent of a 4.5 m high location.

Initial simulations illustrated that the local industry noise contribution was insignificant. Figure 8 shows the acoustic mappings for industrial noise, road emissions and the superimposing of both. It is clear that the most significant contributor is the traffic.

Further study was performed to better understand the effect Huron Church Road had on the traffic noise emissions. Shown in Figure 9 are the daytime noise calculations, both including and omitting Huron Church Road.

Interpreting these images reveals how greatly Huron Church contributes to the overall environmental noise pollution in the area. During the daytime, Huron Church Road contributes to an increase of 3% for levels greater than 55 dBA. Further, 61% of the map achieves a sound level greater than 55 during the day. A summary of the results for daytime noise calculations versus percent area is shown in Figure 10.

Reverse Engineering

Once a reliable theoretical contour was produced, the next step to engineer was a comparison of the modeled theoretical data against the actual data logged from field measurements.

Field Work. Strategic points of interest were selected to optimize the accuracy of the model. Figure 11 shows the study area and details where the noise readings were taken.

The 24-hour readings were collected in 72, 20-minute intervals. This allowed for the conversion of readings into day and night values that would later be used in reverse engineering the noise model. Once all the field data were collected, the same 3D model used for the theoretical simulations was utilized. This would provide a common base for both theoretical and field data to be compared.

The process taken to achieve the desired contour involved implementing "receptor points" into the model. The receptor points represented the location of where each individual reading was taken and the A-weighted noise levels recorded. To produce the desired noise contour, Lima uses powerful algorithms to reverse engineer the values. For the first simulation, road data are input and a noise contour is generated. The reverse-engineering process of a map makes use of collected data points and simply reverses its calculations to obtain road values. The process taken with theoretical emission calculations is done backward. Once Lima reverse-calculates the road emissions, it produces a noise contour.

Table 1. Statistical comparison of predicted noise level between original and reverse engineered.

Reading, dBa	Non-Reverse Engineered Area of Influence, m²	% Area	Reverse Engineered Area of Influence, m²	% Area	Diff., %
35	300	0.00	400	0.01	0.00
40	4375	0.07	7950	0.13	0.06
45	120850	2.01	142575	2.37	0.36
50	838100	13.95	859250	14.30	0.35
55	1367250	22.75	1476225	24.57	1.81
60	1223500	20.36	1187475	19.76	-0.60
65	881075	14.66	851400	14.17	-0.49
70	831900	13.84	760475	12.66	-1.19
75	512650	8.53	472400	7.86	-0.67
80	149325	2.49	163725	2.72	0.24
85	78500	1.31	85775	1.43	0.12
90	1025	0.02	1300	0.02	0.00
95	0	0.00	0	0.00	0.00
Total	**6008850**	**100.00**	**6008950**	**100.00**	**0**

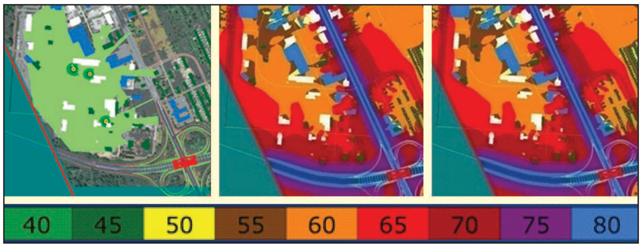

Figure 8. Initial noise mapping results for industrial sources, road emissions and superimposing of both sources.

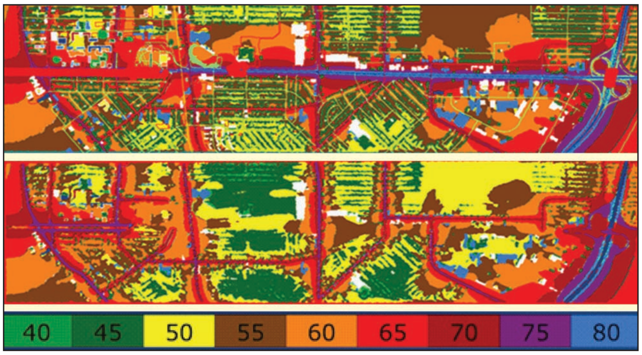

Figure 9. Predicted daytime noise emissions with (upper) and without (lower) effect of Huron Church Road traffic noise.

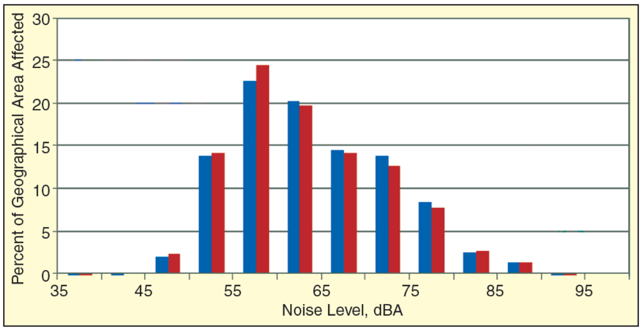

Figure 10. Summary of daytime noise calculation results versus percent area with (blue) and without (red) noise contribution from Huron Church Road.

Figure 11. Sound level meter locations where data were collected to "reverse engineer" Lima model calculations.

Figure 12 shows is an image of the reverse-engineered noise contour along with the original noise contour for comparison.

While the images look similar, small variances can be found in the modeled results. Utilizing Lima's statistical capabilities, a comparison of the two different maps yielded minimal differentiation in noise levels. Table 1 compares the two daytime noise level models.

Although minor differences exist, the noise contours are largely similar. Several assumptions were required to develop the model that provided potential sources of error. As stated previously, assumptions were made regarding residential building heights and traffic contributions from residential roads. Sources of error located in the reverse-engineering calculation involve the 24-hour L_{eq} readings as they fail to account for variances in day-to-day traffic volume. These simulations provide a good representation of expected noise levels, but depending on daily traffic volumes, levels may increase or decrease. Overall, both modeled contours display similar readings, demonstrating good accuracy of the model. It also

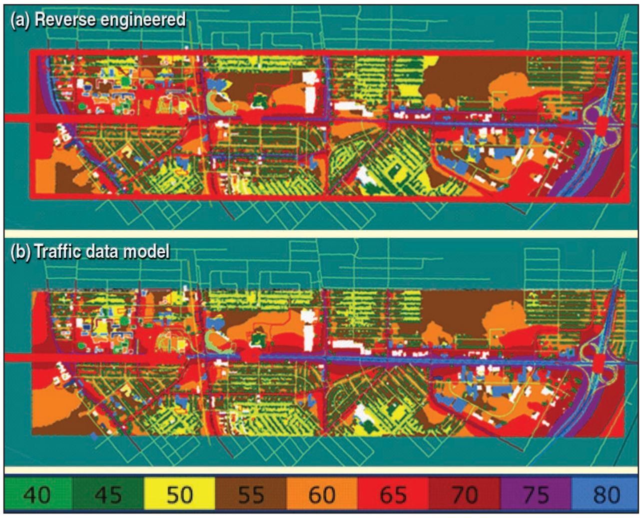

Figure 12. Reverse engineered noise contour and original noise contour.

clearly demonstrated that the Lima-produced model is effective in calculating the required environmental noise emissions and allows for accurate analysis of the results. Implementing and analyzing various mitigation solutions can also be executed with ease and peace of mind that accurate results will be generated.

Conclusions

Upon completing all the initial calculations intended for this project, WENMI realized it could still design mitigation techniques and display them with Lima's modeling capabilities. The group used results obtained from reverse engineering and progressed toward composing research papers that discuss incorporating noise abatement solutions. Three papers are being submitted for publication:

- An approach to generating and calibrating an environmental noise contour map
- The green corridor and its effect on noise levels and possible mitigations
- A study of modelling pre-existing traffic noise mitigation

Along with the initial results, WENMI hopes awareness regarding noise pollution and its effects will be increased. It also hopes that 3D modeling will be implemented in optimizing urban planning for environmental noise consideration. This project demonstrated that large-scale noise modeling is both feasible and accurate for environmental noise prediction of all common sources of community noise. With respect to Huron Church Road, there are large areas that exceed ministry guidelines for noise levels. We hope that the results obtained in this study will provide motivation for the public and government at all levels to take a proactive approach to mitigating the present problem. S|V

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